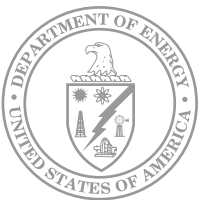
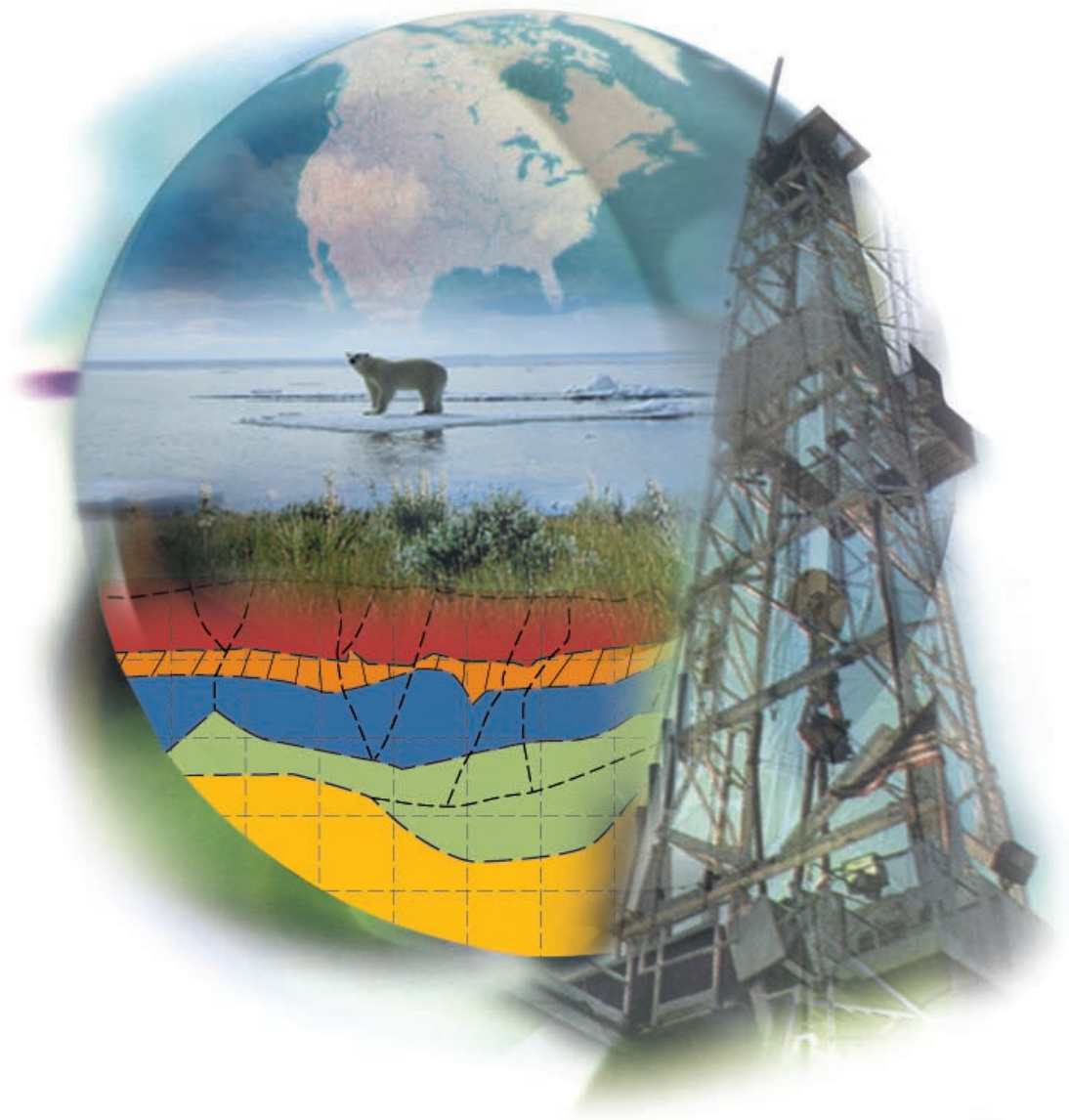




U.S. DEPARTMENT *of* ENERGY
OFFICE *of* FOSSIL ENERGY



ENVIRONMENTAL BENEFITS
of ADVANCED OIL *and* GAS EXPLORATION
and PRODUCTION TECHNOLOGY



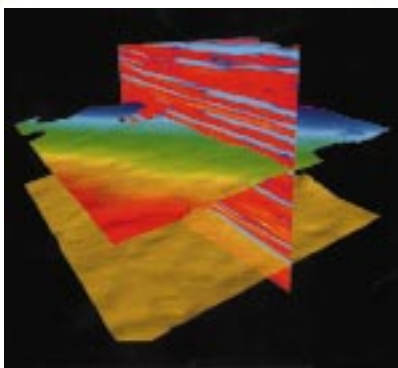


CUTTING-EDGE TECHNOLOGY REVOLUTIONIZES EXPLORATION

The Gulf of Mexico's coastal transition zone is among the most prospective, unexplored oil and gas regions in the country. Yet, the region's geological and operational complexities have long hampered E&P activities. Now, thanks to next-generation 3-D seismic imaging, new drilling capabilities, and associated technologies, the zone is coming alive with new discoveries—including successful strikes in old fields. For example, Spirit Energy '76 (Unocal Corporation's E&P unit) recently began drilling deeper targets, based on newly acquired 3-D seismic data, around the 40-year-old Vermilion 14 field, located in State waters off central coastal Louisiana. Barry Gouger, Central Gulf asset manager, reported in 1998 that 10 million barrels of oil equivalent had been added to the field's reserves since the acquisition of 3-D seismic.

"The 3-D seismic has allowed us to sharpshoot for bypassed pay and new targets within the field and new opportunities around the field," Gouger explained. "The effort and expense of acquiring 3-D seismic over these older giant fields is well worth it. We are finding significant new reserves in and around the field, and just as important are the wells that we do not drill because of the 3-D coverage." It's a story being replicated throughout the Gulf transition zone, where 3-D seismic is minimizing environmental disruption by effectively targeting new prospects and extending the life of existing reservoirs.

Source: American Oil & Gas Reporter, April 1998



Advanced technologies like seismic imaging have raised exploration success rates by 50 percent or more.

Photo: Texaco Production Operations

SEARCHING FOR HYDROCARBONS today is about as far removed as possible from old movie images of wildcat drillers hoping for a gusher. It involves teams of geologists, geophysicists, and petroleum engineers seeking to identify, characterize, and pursue geologic prospects that may contain commercial quantities of oil and gas. Because these prospects lie thousands of feet below the earth's surface, uncertainty and trial-and-error pervade the exploration process. It is a painstaking and hugely expensive enterprise, with low success rates. Historically, new field wildcat exploration has succeeded at a rate of one productive well for every five to 10 wells drilled.

Over time, the more easily discovered resources in the United States have been found, developed, depleted, and then plugged and abandoned when they reached their

economic limit. New fields now being discovered in the United States are generally smaller in size and found in deeper, more subtle, and more challenging geologic formations. Yet, despite the increased difficulty of discovering remaining domestic resources, technology developments have enabled the oil and gas industry to maintain or, in many cases, improve upon, historical levels of exploration success.

Today, experts can interpret geological and geophysical data more completely; manage, visualize, and evaluate larger volumes of data simultaneously; and communicate interpretations based on these data more accurately.

Advanced techniques now allow the scientist to virtually "see" the inside of the formation. Three-dimensional seismic technology, first commercially available nearly 25 years ago, bounces acoustic or electrical vibrations off subsurface structures, generating massive amounts of data. Then powerful computers manipulate the data to create fully visualized multidimensional representations of the subsurface. Even more exciting is 4-D time-lapse imaging—an emerging technology developed only within the past 5 to 10 years—which adds the dimension of time, allowing scientists to understand how the flow pattern of hydrocarbons changes in the formation over time.



Fundamentals of Exploration

Searching for Oil and Gas

Exploration includes:

- Surveying and mapping surface and subsurface geologic features to identify structures where oil and gas may have accumulated.
- Determining a geologic formation's potential for containing commercial quantities of economically producible oil and/or gas.
- Identifying the best location to drill an exploratory well to test the structure.
- Drilling exploration and delineation wells to determine where hydrocarbons are present and to measure the area and thickness of the oil- and/or gas-bearing reservoir.
- Logging and coring wells to measure permeability, porosity, and other properties of the geologic formation(s) encountered.
- Completing wells deemed capable of producing commercial quantities of hydrocarbons.

Fewer Dry Holes, More Production and Reserve Additions per Well

IMPROVEMENTS IN 3-D SEISMIC AND 4-D time-lapse visualization, remote sensing, and other exploration technology allow explorationists to target higher-quality prospects and to improve success rates by as much as 50 percent or more. The result: fewer wells need to be drilled to find a given target, and production per well is increased, in some cases by 100 percent.

Today, fewer than half as many wells are required to achieve the same reserve additions as two decades ago. Annual reserve additions for new exploratory drilling have quadrupled, from a per-well average of

about 10,000 barrels of oil equivalent (BOE)* in the 1970s and 1980s to over 40,000 BOE in the 1990s.

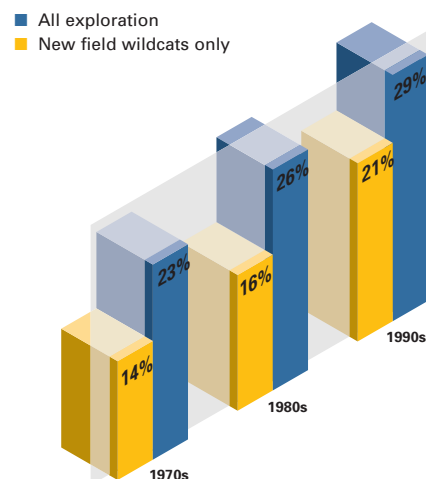
Thanks to today's technology, whole new categories of resources, considered inaccessible just 20 years ago, are now counted as part of the domestic resource base. Advances in exploration drilling technology have been particularly dramatic in deepwater areas, where significant expansion of the known resource base has resulted.

In aggregate, technology improvements have slashed the average cost of finding oil and gas reserves in the United States from roughly \$12 to \$16 per BOE of reserves added in the 1970s and 1980s to \$4 to \$8 today.

**Natural gas is converted to "barrels of oil equivalent" on the basis of 0.178 barrels of oil per thousand cubic feet of gas.*

Exploration Success Rates

Despite a dwindling resource base, U.S. exploration success rates continue to improve.

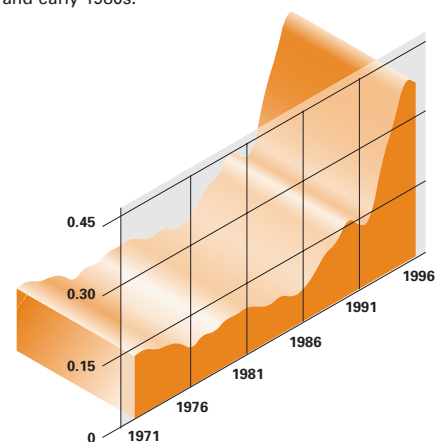


Source: American Petroleum Institute

BOE New Reservoir and New Field Reserve Additions per Exploratory Well

(Million barrels of oil equivalent per well)

The volume of reserves added per exploratory well has increased dramatically since the 1970s and early 1980s.



Source: U.S. Department of Energy



On the Cutting Edge

The sharply increased success rates and well productivity improvements attributable to advanced exploration technology yield substantial environmental benefits. Fewer wells drilled means reduced volumes of wastes to be managed, such as cuttings and drilling fluids (which lubricate the drill bit, circulate cuttings, and stabilize wellbore pressures).

New Resources in Old Fields

IMPROVEMENTS IN EXPLORATION and production technology enable operators today to better tap resources that remain in existing fields. Advances in 3-D and interwell seismic technology allow operators to take another look at older producing areas, such as the fields in Appalachia, California, and West Texas, and see untapped zones of hydrocarbons that were bypassed or could not be seen in the past.

Improved computer-processing technology and interpretation software allow older seismic data to be reprocessed and reevaluated.



Photo: Sundowner Offshore Services

Exploration Applies High Technology

Advances in widely varied technical disciplines have boosted exploration efficiency over the past 20 years:

- **Advances in computer power, speed, and accuracy**
- **Remote sensing and image-processing technology**
- **Satellite-derived gravity and bathymetry data that enable remote sensing for offshore deepwater exploration**
- **Developments in global positioning systems (GPS)**
- **Advances in geographical information systems (GIS)**
- **Three-dimensional (3-D) and 4-D time-lapse imaging technology that permit better characterization of geologic structures and reservoir fluids below the surface**
- **Improved logging tools that enhance industry's geoscientific understanding of specific basins, plays, and reservoirs**
- **Advances in drilling that allow explorationists to more cost-effectively tap undepleted zones in maturing fields, test deeper zones in existing fields, and explore new regions**

Once untapped zones are identified, new techniques for sidetrack drilling (drilling a lateral extension from an existing wellbore) and deeper drilling from existing wells can allow some of these resources to be developed without drilling new wells or disturbing previously undisturbed areas.

Exploring New Frontiers

NEW DEEPWATER DRILLING TECHNOLOGY enables exploratory drilling in ever deeper offshore waters, making promising new resources accessible for the first time. Advances include high-technology floating

drillships, jackup rigs, semisubmersible drilling rigs, and modular rigs. When commercial quantities of resources are discovered, discovery wells are capped until permanent production platforms can be set in place. Where dry holes are found, wells are plugged and the rigs are redeployed swiftly. As offshore technology extends exploratory reach, the industry continuously pushes to advance development and production technology to operate cost-effectively in ever deeper waters.



ENVIRONMENTAL BENEFITS of ADVANCED E&P TECHNOLOGY

THE 4-D DIFFERENCE

At BP Amoco/Shell's Foenhaven field, estimated recovery rates of oil-in-place are expected to reach 65 to 70 percent with 4-D seismic, compared to 25 to 30 percent with 2-D technology and 40 to 50 percent with 3-D technology.



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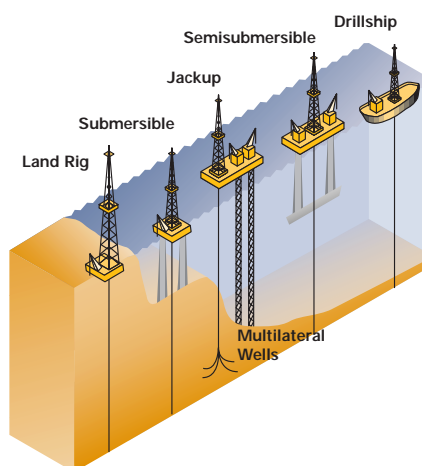
Outfitted with state-of-the-art electronics and computers, seismic survey vessels collect and process invaluable subsurface geological data to aid offshore exploration.

More Advances in Exploration Technology

BEYOND ADVANCED IMAGING, other new exploration approaches are being applied throughout the country to reduce environmental impacts, particularly in sensitive environmental areas. Redesign of drill rigs has minimized surface loading. Seismic techniques also have been redesigned to reduce impacts resulting from explosive shocks—for instance, through more flexible positioning of shotholes and geophones, redesign of shothole loading procedures, and use of ramming instead of drilling to set charges in hydrophones. These new acoustical and vibration devices replace explosives for generating seismic signals onshore and offshore, reducing noise, and protecting human, marine, and animal life.

These advances are enabling exploratory drilling in water depths of a mile or more, extending drilling seasons in the Arctic without disturbing the tundra or wildlife migratory patterns, and opening commercial development prospects in complex geological basins.

Exploration Drilling Techniques
from Land to Deepwater



Source: Minerals Management Service

BEYOND THE OIL PATCH

- Advances in 3-D and 4-D seismic technology and earth-imaging systems have helped in the understanding of subsurface fluid flow, not just for oil and gas, but for groundwater monitoring and pollutant transport.
- Advances in geological and geophysical technologies have assisted in improving our overall understanding of "earth systems," or the major processes influencing activity in the earth's crust.
- Improved logging and interpretation technologies have helped us learn more about the characteristics of the earth's crust.

Exploration Drilling Technology
Evolution in Offshore

